Developing and Optimizing the Artificial Limb Prosthesis Based on pH Change at Neuromuscular Junction

A PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

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By

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CERTIFICATE

This is to certify that research project report entitled "**Developing and optimizing the artificial limb prosthesis based on reverse mechanotransduction**" submitted by **Ravi Dadsena**, in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Biotechnology and Medical Engineering with specialization in Biomedical engineering at National Institute of Technology Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any Degree or Diploma.

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(**Ravi Dadsena**

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ABSTRACT

Until now, the biological information that has been made use for the development of artificial limbs based on electro-mechanical coupling is from EMG signals, EEG signal and/or local signals of neuronal excitation. While all these methodologies are successful experimentally, they also possess few drawbacks such as inability to pick up minute neuronal signals, corrosion of the internal electrode leading to toxicity and aberrant reading of those bio-signals. In the current study an innovative approach of developing an artificial limb based on change in pH at the neuromuscular junction (NMJ) has been proposed. In humans like any vertebrates, the motor movements of the appendages are commanded by the motor area of cerebral cortex voluntarily when a will to act is generated. This is followed by neuronal excitation that passes through NMJ to excite/contract different group of muscles. The muscle excitation is preceded by action potential development that is initiated, maintained and terminated by sequential ionic movements in and out of the muscle cell. The major ions involved are Na and K. The change in these ionic concentrations can lead to change in pH at the NMJ that can be interpreted as information sent by the brain. Thus it was hypothesized that the changes in the pH can accurately mimic the intended changes in the amputated limb muscles, and therefore can be used to turn the user's desired motion into actual motion of the limb prosthesis. Briefly, the study utilized a pH-to-voltage converter which converts the pH signals of the neuro-muscular junction into an electrical signal (voltage change). A cut-off voltage was assigned above which the limb moves that exactly simulates the role of action potential in muscle contraction. The movement of the artificial limb was implemented by the usage of a DC motor that can be switched on or off through a microcontroller above or below the cut off voltage respectively. The microcontroller, AT89C52 was used for function coding of the system that regulated the movement amplitude, and range for the prosthetic limb. The connection between the DC motor and microcontroller was implemented using ICL293D integrated circuit. The overall success of the study lies in the efficiency of the sensitivity of pH meter that can record the smallest change in pH so that a high fidelity prosthetic limb motion can be generated. This study can be further implemented by using ion specific electrodes to monitor the change in specific ion concentration as information/input. A high fidelity system thus developed can be projected to the movement of fine moving prosthetics like digits.

Keywords: prosthetic limb, neuromuscular junction, voltage-regulated limb movement

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CHAPTER 1

INTRODUCTION

1.1 Artificial limb

According to the dictionary meaning, limb is defined or meant as a structure or part of human body parts – arms or leg. When a person meets with an accident, or due to cancer or any other disease through which someone has lost his one of the arm or leg, then artificial part called "limb" is introduced. This is done to make the person mentally and physically active and he/she can do their work without any support [1].

Figure 1.1 A artificial limb[27]

Artificial limb is a mechanical replacement for human arm. Function of artificial limb, which is also called prosthesis, such as movement of hand, or picking up of any material can be done by using artificial limb.

1.2 History of artificial limb

The first artificial limb was artificial leg which was invaded in 300B.C. in Italy. It is made up of iron and bronze. The first artificial limb arm was inserted into the Roman Scholar Pliny the Elder which was made up of iron and bronze in the year(23-29A.D.), which was successful and he was able to back to the war.

Then comes the Dark Ages era which was from 476 – 1000, not much but yet, some advancement in artificial limb takes place. In this era, it was common for people to make artificial limb even the armorers, tradesman began to contribute in making the artificial limb. In this period, limbs were made of iron, wood, copper, steel. In 1512, an Italian surgeon noted that the artificial limb can open his purse or sign.

Moving towards modern era, many advancement since then has been done. As civil war continues, more number of people come into the club of prosthesis. In addition, one can say that all these developments have done so that man can do functions and cannot have artificial limb but also can do their own functions [2].

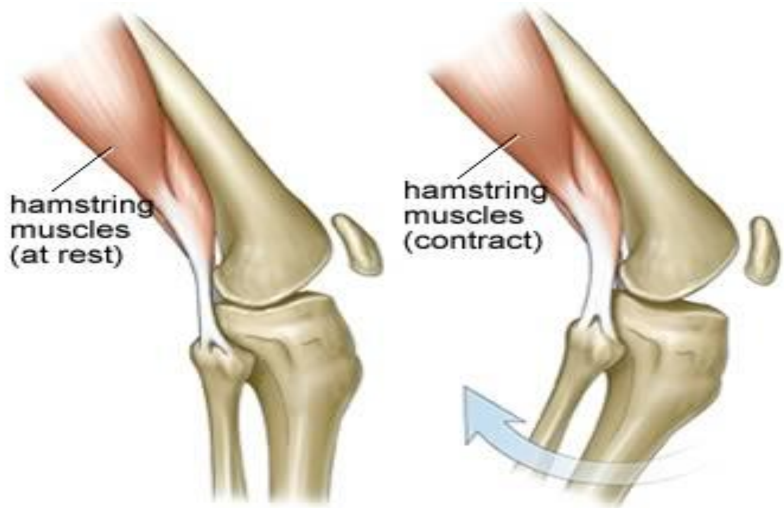


Figure 1.2 Muscle contraction and relaxation

1.3 Prosthesis

Prosthesis is used for replacing the arm or leg which is lost due to some accident or by birth or by most commonly trauma. Trauma is the most common cause of prosthesis. Infants who were born with trauma or any congenital weakness likely to have prosthesis in an early age.

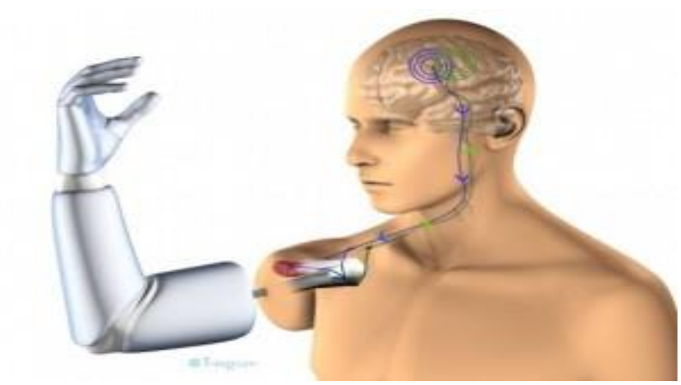


Figure 1.3: Limb prosthesis[27]

It was first found in the book of VEDAS from Sanskrit, India, which was written between 3500 and 1800 B.C. In this book, there is written that when there is a battle with the near territory –

Queen Vishpla – a warrior queen lost her one leg. After some years, she was fitted with the iron made prosthesis limb so as to make her come back to the battle for her kingdom [3].

Many Egyptians has also used the artificial limb even, when they bury their monarchs or nobles. It was believed that if the person is not had all its parts during the funeral process, their spirit born with the weakness in his afterlife. These limbs were made artistically.

In 2000, in ancient Egypt, archaeologists found the oldest artificial body part. The artificial part was believed to be 3000 years old. The artificial body part was the big toe of a woman at that time at the time of her death which was around 50-60 years old. The limb found was laced with the leather sleeve. The artificial limb – toe – has three bendable joints and sides indicate that it has been used during the women's lifetime.

Figure 1.4: prosthesis limb[29]

Archaeologists found in ancient Rome that prosthesis that were made were used to replace the lower legs. These were found in 300 B.C. and are made up from wooden core coated with hammered metal plates. The artificial limb was then strapped with leather to the remaining part and used to replicate normal walking. This prosthesis was incorporated by the blacksmiths, armour makers and metal workers. These were those who were skilled in blending of wood, Metal and leather.

Figure 1.5: 19th century wooden leg [28]

Losing a body part, at that time, was considered to be unsightly and was embarrassing but something can be done for the people to overcome their weakness. Through the Middle Ages, blacksmiths and armour makers were considered to be the best maker of prosthesis. People or a soldier who were injured during the battle goes to armor maker and made a replacement limb so that they can return to their battle. However, these prosthesis limbs were very heavier [4].

The high demand for the prosthesis occurred when Civil War in America takes place. This encourages the makers of prosthesis to have some advancement in the limb. In 1818, a German dentist, Peter Bellif, discovered the prosthesis limb of arm which works on the movement of the opposite shoulder. Apart from the history, today, the number of people undergoing prosthesis process is between 40,000 to 1,000,000 in USA alone. Technology is advancing and thus, the process of making prosthesis limb. Materials which are common for making of prosthesis limb these days are plastic and carbon fibre so as to make the prosthesis limb lightweight and more durable. Materials common for making prosthesis arms are silicone, which is common and is comfortable to wear. Computer technology is likely to be more advanced during these coming years.

The basic difference between the modern prosthesis and that of the past was the artificial limb and the patient's limb.

The recent development in prosthesis is being discovered in U.K. called "bionic hand". It started to help the needy children with congenital weakness in the year 1963. They come out with the prosthetic hand with all the fingers working. This came into existence in the year 2007 and produced by the company – “touch bionic” and sell. This company gave this prosthetic hand a name –“i-Limb” [5].

This device was successful and have implemented to more than 200 people including children and soldiers. This company is now involved in making full arm so that many lives can be saved and they can live their normal life. Children who have prosthesis limb can now make their better future as they have overcome their disability. Advancements will continue in this field so as to live the satisfactorily life. Many developments have been made and some are yet to make and will continue the same.

1.4 NEUROMUSCULAR JUNCTION

The neuromuscular junction links the nervous system with the muscle system through synapses between muscle fibres and motor neurons. A neuron activates a muscle to contract at this particular junction .Upon the arrival of the action potential at the end of the motor neuron. Voltage gated calcium channel open allowing calcium influx to the end of the neuron .Calcium binds to the sensory proteins on the synaptic vehicles resulting in the vehicle fusion with plasma membrane and release of neurotransmitters at the synaptic cleft [6].

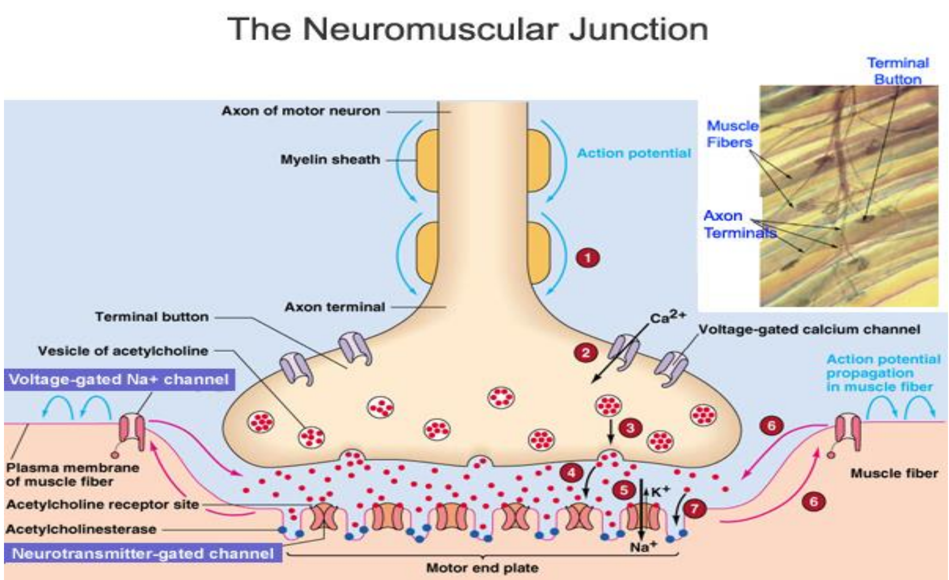


Figure 1.6: Neuromuscular junction[30]

1.5 NEURONS

Neurons and its functions are involved in our everyday life. It involves our brain (nervous system). Our nervous system contains billions of cells called neurons. Neurons carry messages through electrochemical impulses. Our brain has 100 billion (approx.) neurons.

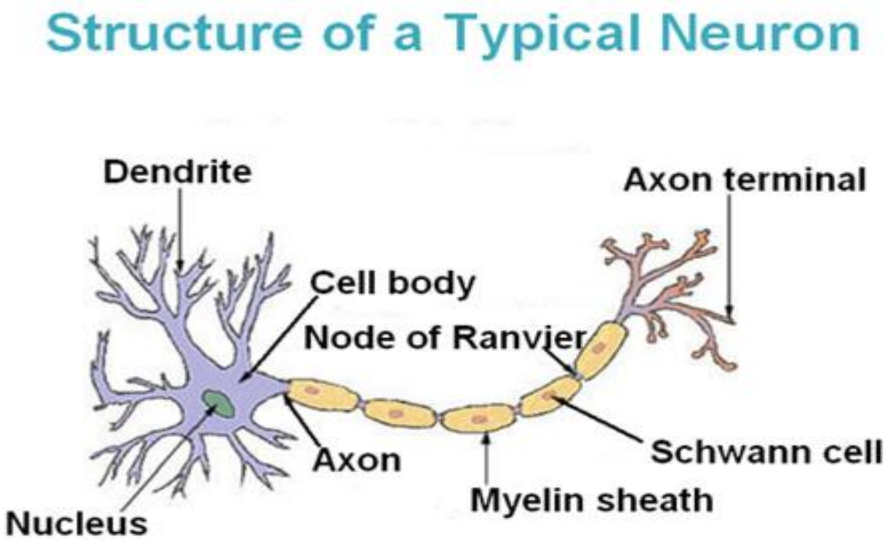


Figure 1.7: structure of typical neurons[31]

Neurons can be of many shapes and sizes and can be as small as 4 micron wide and can as large as 100 microns wide. Neurons are supposed to be homogenous to other cells of a body because:

1.Neurons are bounded by the cell membrane.

2.Neuron needs a nucleus that consists of genes.

3.Neurons constitute mitochondria, cytoplasm, and other organelles.

4. Neurons perform various fundamental cell methodologies, such as, protein amalgamation and vitality creation. Although, some difference lies between neurons and the other cells. They are stated as follows:

1. Neurons contain specialized cell parts called dendrites and axons**.** Dendrites bring electrical signals to the cell body and axons carry the information away from the cell body.

2. Neurons establish communication with each other through an electrochemical process.

3. Neurons contain some specialized structures and chemicals such as synapses and neurotransmitters

Nervous system functions are interconnected. Below figure describes the functions of nervous system. Nervous system has the following functions:

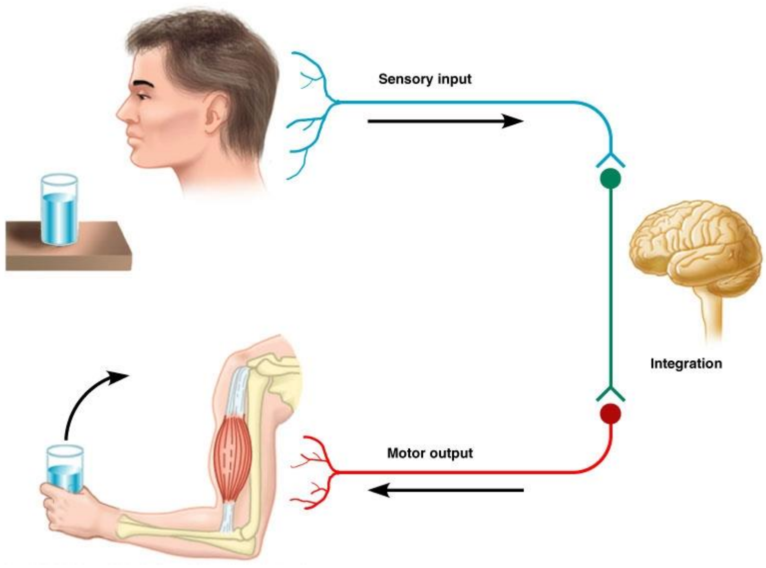


Figure 1.8 - Nervous system functioning

1. It transmits sensory information i.e. stimuli to the central control center.

2. It is involved in the processing, integration, and interpretation of incoming sensory information (stimuli)

3. It also transmits motor nerve impulses to effector organs and tissues, such as, muscles and glands.

Neurons can be classified on the basis of two types:

1. Structural classification.

2. Functional classification.

The above two types can also be further classified. The below figure showed the further classification.

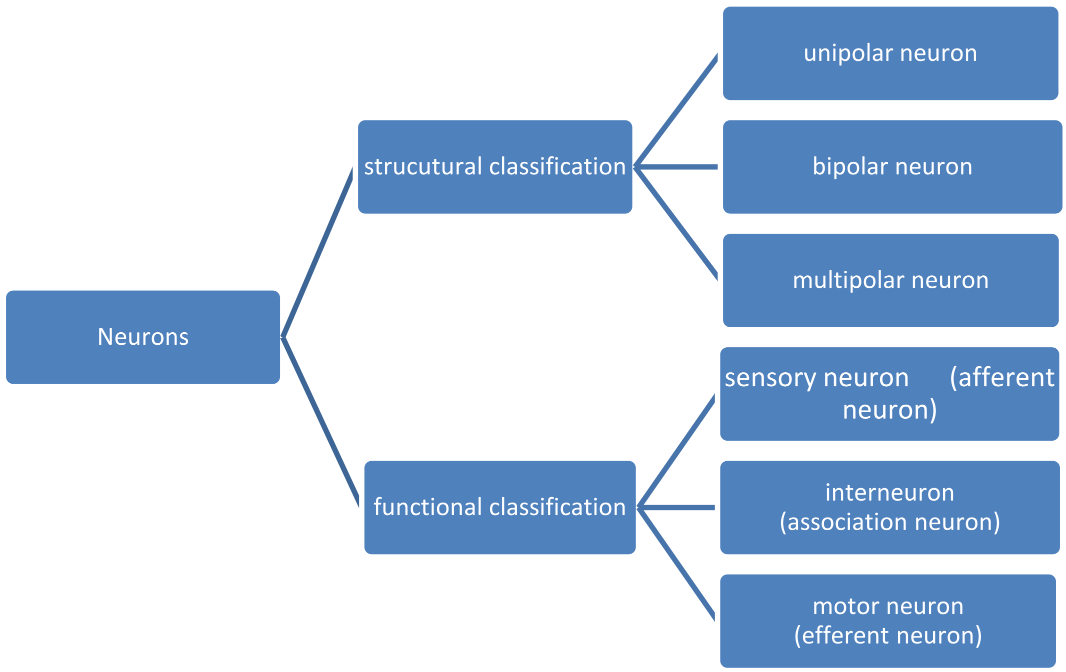


Figure 1.9 - Classification of neurons

sensory neuron afferent neuron i.e. A neuron conducting stimuli from a recipient cell or organ in the form of nerve impulses inwards to nerve centers in the brain or spinal cord motor neuron efferent neuron .A neuron which relays impulses outward from the brain or spinal cord in order to regulate the action of a gland, muscle, or other effector tissue. Interneuron association neuron .A nerve cell that is found entirely within the central nervous system acting as a link between motor neurons and sensory neurons or connecting with other interneurons in a pathway within the CNS.

Unipolar neuron - One of the structural classifications of neurons. Only a single process leaves the cell body of an unipolar neuron . This single process then divides near to the cell body into a trunk to supply the branching dendrites with incoming signals and an axon with outgoing signals. Unipolar neurons are typical sensory neurons with receptors located within the joints, muscles, skin, and internal organs. Their axons are usually long, terminates in the spinal cord, while their dendritic trunks length may vary.

Bipolar neuron –Another type of structural classifications of neurons. Two processes leave the cell body of a bipolar neuron .In this neuron, the dendritic tree comes out from one end of the cell body, while the axon comes out from the opposite end. Branching of the dendrites in bipolar neurons is typically limited, and the axons of such neurons are generally short in length. Bipolar neurons are sensory neurons associated with receptor visual and auditory system organs. The narrow fields generated by the short dendrites of these neurons lie the concise encoded visual and auditory information representing physical signals from the external world. Without this narrow encoded sensory information, the resolution of hearing and vision would have been reduced.

Multipolar neuron –Third type of structural classifications of neurons.Multiple branches leave the cell body of the multipolar neuron.Nunberof dendrites of the multipolar neuron allow the extensive integration of information coming from multiple neurons. The axons of such neurons are generally long, therefore allowing this integrated information to affect remote regions of the nervous system. Below figure shows the different types of stuructral classification of neurons.

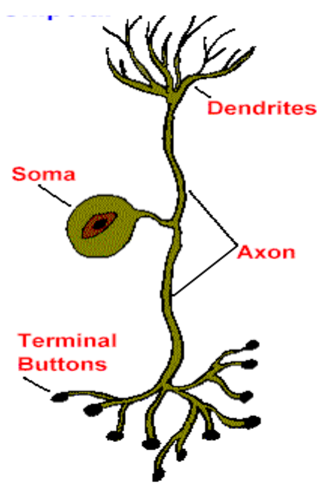


Figure 1.10 - Unipolar neuron[31]

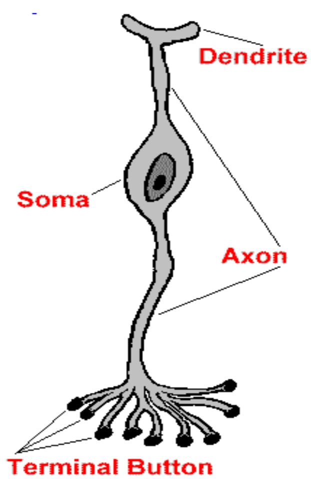


Figure 1.11: Bipolar neuron[31]

1.6 Objectives:

1. Improvisation of a hinge system (previously developed in the laboratory) that will replicate mechanical joint.
2. Utilizing the pH change mechanism to attain mechanical joint movement as a response in a biological fluid using a pH electrode and microcontroller assembly.
3. Ultimately, insertion of the control unit (pH electrode-microcontroller) and end organ (mechanical joint) in an embedded system that can project the neuron-neuromuscular junction-muscle fiber sequence in the systemic architecture of the human body.

CHAPTER 2

LITERATURE REVIEW

The Prosthetic care is the oldest known medicine from the 5th Egyptian sovereignty (2750-2625 B.C) where the splint for prosthetic care was unearthed by the archaeologists. It was since then, prosthetic care was mainly done by using simple wooden splints to control the body & the external powered systems using microprocessors technology. The main goal of this artificial device is to provide an aid to a disabled person to perform the function of the amputated limb. There are various other applications which include cosmetic appearance and feeling of the wholeness etc.

These are the following paper which describes the various methods of development of artificial device which provides the lost body parts or prosthetic cares are:

This paper mainly focused on the prosthesis of the upper limb, where a person who has lost his/her upper limbs was provided with a newly designed mechanical replacement. There are 5 different types of upper limb prosthesis are available in the market. They are cosmetic, body powered, externally powered, hybrid powered and activity specific [7].

- Main use of the cosmetic prosthesis is as an aesthetic appeal. It has little or no functional use.
- The upper limb's body powered prosthesis having high durability and reliability provides good, interoception with a low maintenance. The low comfort level is because of the harness straps, for which the performance is significantly reduced.
- A good comfort level with good performance is delivered by externally powered prosthesis. As this is more intricate, operating it is more complex, therefore requiring higher continuance and less reliability.

The combination of both body powered & externally powered makes hybrid powered, while the particular actions are carried out by targeting the activity-specific. There are various upper limb prostheses commercially available which include:

- The "Utah Arm" from Motion Control Inc.
- The prosthesis controlled by cable from Otto Bock.
- The Boston Elbow and the Bowden cable arm.

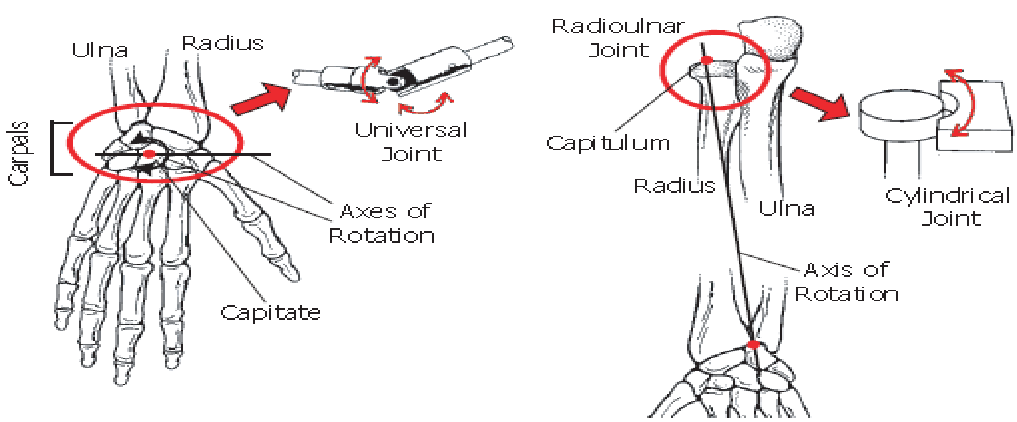
In addition, body powered cable activated systems tend to limit the motion range of amputee & other required motions to control the effect which are considered as unnatural.

- Present day arm prosthesis have lower degrees of freedom(DOF) [8] than the normal arm. That's why they are not as experienced as the normal human arm.
- Previously joints are also having single DOF joints, and if the DOF of the joints are increased, It increases the complexity and weight of the activated system.

The needs of the artificial device users can be obtained, by exploring the potential path i.e. through bio-inspired solutions. In past years designers of the robot[9, 10] started to observe the natural solutions and thus tried coping these biological solutions. These new manipulator designs, control strategies and were thought to reproduce motion like the humans and also to get mobility, versatility, redundancy and compliance like the humans. Hence, this potential exploration path will be adopted in future in order to develop prostheses with improved characteristics.

2.1 Conceptual Design:

The human arm anatomy is examined so that a bio-inspired conceptual design solution can come up. The ulna, radius and carpals assemble themselves to form the lower human arm (i.e. forearm & wrist). Pitch motions (i.e. radial/ ulnar deviation) can be present in the wrist around the radio carpal and midcarpal joint axes. It can also have motions like extension & flexion. Hence, a similarity between a human wrist and a universal joint can be seen (as shown in Figure-a).
In addition, rotation of the wrist can take place about the forearm axis. This rotation is because of the relative movement between the ulna and radius bones (as shown in Figure-b).Thus, the wrist motion is similar to that of a spherical joint.



(a) (b)

Figure 2.1 Design of a Cable-driven wrist Prostheses [11]

The approval of modern artificial limbs by amputees would be significantly increased by using a system that provides appropriate categorized distally referred sensations of touch and joint movement, and by a more natural control mechanism the improvement of limb prostheses can be done [12, 20]. In addition to this, the phantom limb pain, affecting mainly up to 80% of amputees, can be altered in some cases by sensory training which restricts the extent of somatosensory cortical reorganization. [21, 24].

It is believed that these following problems can be solved by a direct neural interface with nerve fibers in the peripheral nerve stumps which allows feedback information to be provided through sensory pathways originally associated with the missing parts of the arm, and allows control signals to be derived from neural activity generated by the amputee while attempting to move the missing elbow, wrist, or fingers.

In present studies the appropriate distally referred sensory feedback about joint position and grip force from an artificial arm is demonstrated which can be provided to an amputee through several peripheral nerve stimulations, and the motor command signals that is appropriate for controlling joint position and grip force could be obtained by recording the activity of the motor neuron from these nerves.

This work presents the progress of a sensor for recognizing human muscle contraction, capturing myoelectric signals**,** in order to control a myoelectric prosthesis [25] of superior limb.

Signal examination is carried out by using software running in a microcontroller which decides how the artificial hand can open or close. The addition of new state functions (for example, if the hand is open, close, semi-close, etc.) to the prosthesis cab ne easily done with a few simple changes in the microcontroller program [26], without any changes in the hardware .

This strategy is mainly proposed for controlling the artificial hand, based on the myoelectric signal, and using a servomotor motor which drives the prosthesis mechanisms. Through this way, a more accurate and easier control of the movement of the prosthetic device can be achieved by the patient, thereby leading to a faster adaptation. Thus various kinds of activating of the artificial hand can be obtained by a simple binary signal or through the myoelectric signal pattern analysis [27].

CHAPTER 3

MATERIALS AND METHODS

3.1Ringer lactate solution

In the current project Ringer lactate solution was used as a biological fluid whose pH is approximately equal to 7. It is a standardized sterile physiologic– ie, isotonic– 0.9% solution containing calcium chloride, KCl, NaCl, sodium lactate.

Table 3.1: Ringer lactate solution composition

Ingredient(m.w)	mM	Grams per Liter
Nacl (58.44)	130	7.60
Kcl 74.55)	6.0	0.45
$Mgcl_2.6H_2O$ (203.3)	0.7	0.143
$NaH_2PO_4.H_2O$ (137.99)	0.29	0.04
$NaHCO_3$ (84.01)	19.6	1.65
$Na_2HPO_4.7H_2O$ (268.1)	1.3	0.35
$CaCl_2.2H_2O$	3.0	0.44
D-glucose (180.16)	11.0	1.98

3.2 pH probe amplifier

Figure 3.1 shows a pH probe amplifier circuit used to convert change in pH to voltage with the assistance of microcontroller. The microcontroller utilized here was AT89C52. pH indicates the the acidity or alkalinity of medium or concentration of H+ ions. The pH cathode was made out of two primary parts: a glass terminal and a reference anode as indicated in Figure 3.2. pH can be estimated specifically by measuring the voltage difference between these two cathodes. At the tip of the glass anode there is thin membrane which is a particular kind of glass that has the capability of exchanging the ions. It is responsible for sensing the hydrogen ion concentration of the examined solution. The reference anode potential is consistent and is transformed by the reference terminal (Calomel cathode/Standard Hydrogen Electrode) in contact with the reference-fill result that is kept at a ph of 7(nearly equivalent to that of water).

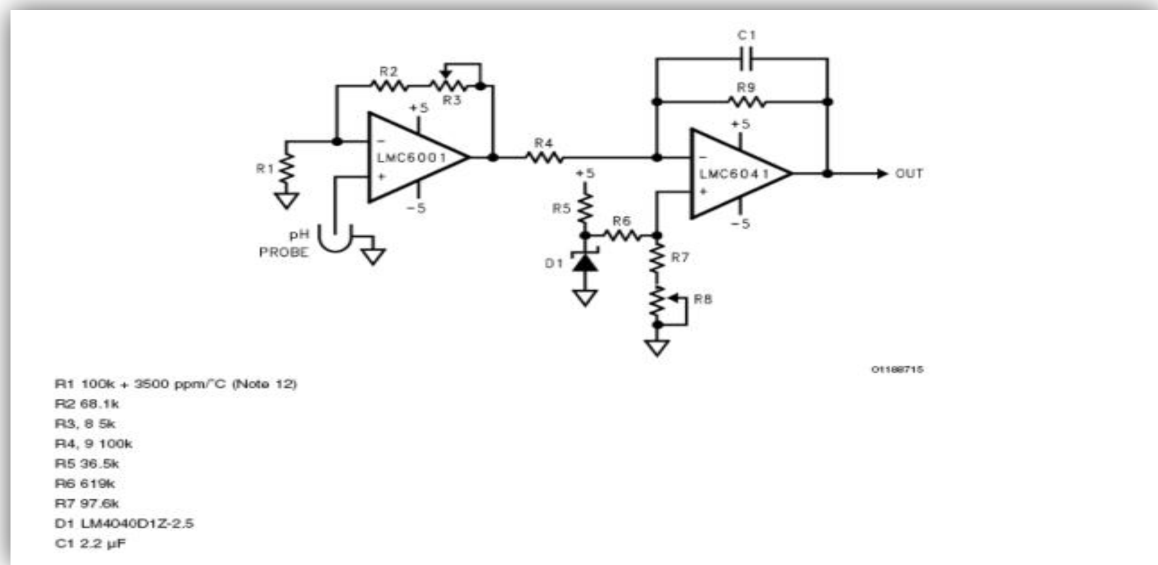


Figure 3.1 pH Probe amplifier circuit diagram

3.2.1 COMPONENTS OF pH PROBE AMPLIFIER

3.2.1a OP-AMP LM741

In the current project a LM741 Op-Amp was used for amplifying the electrical signal. LM741 is the most common Op-Amp and it behaves as a ‘Linear Amplifier’ that are capable of executing mathematical operations like add, subtract, multiply, divide etc. The Operational Amplifier is the highly versatile Integrated Circuit, yet economical and it contains numerous hundred components like BJTs/MOSFETs. The purpose of it is to amplify a weak signal just like a Darlington Pair. The OP-AMP has two inputs, the –ve terminal is referred to as inverting input (at pin 2) where as the positive terminal is known as non-inverting input (at pin 3) and having one output that can be taken from pin 6. The pin configuration of the amplifier is shown in Figure 3.3.

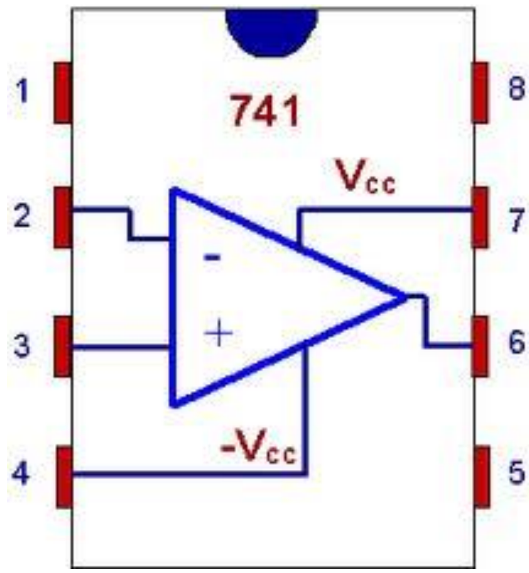


Figure 3.2 Op-Amp pin descriptions

3.2.1b RESISTOR

As known Resistance opposes the flow of current. Resistance makes the system slow and sluggish in nature. Some more examples of resistance are photoresistor, Light Dependent Resistor etc. The SI unit of resistance is Ohm (Ω) (i.e. the ratio of change in unit voltage to change in unit current inside conductor).

3.2.1c CAPACITOR

In the current project a capacitor was used to keep the voltage constant. A capacitor is a "passive element" it stores energy in the form of electric field .Unlike a resistor, a capacitor does not dissipate energy. Instead, a capacitor stores energy in the form of an electrostatic field between its plates. When there is a potential difference across the conductors (e.g., when a capacitor is attached across a battery), an electric field develops across the dielectric, causing positive charge (+Q) to collect on one plate and negative charge (-Q) to collect on the other plate. The capacitor output for DC input is zero. In case of signal processing, the capacitors are also used as filtering element to remove the ripples (AC component present in DC). An ideal capacitor is characterized by its capacitance. Capacitance is expressed as the ratio of the electric charge (Q) on each conductor to the potential difference (V) between them. The SI unit of capacitance is the farad (F), which is equal to one coulomb per volt (1 C/V).

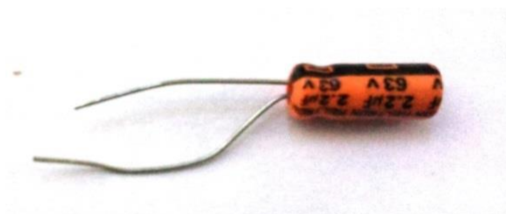


Figure 3.3 Capacitor

3.2.1.d POTENTIOMETER

In the current project potentiometer was used to vary the voltage by varying the resistance. This is done through the slide wire. Potentiometer contains three terminals. Out of the three terminal, one terminal of the potentiometer is connected to a power, source, and another is connected to a ground which behaves as a neutral point. The third terminal behaves like sliding contact across a strip of resistive material. This resistive strip generally has a low resistance at one end, and at the other end the value of resistance increases to its maximum level. The third terminal used for the connection between the power source and ground, and it is generally operated by the user with the help of a knob or lever. The user can alter the position of the third terminal along the resistive strip to manually increase or decrease resistance. The amount of resistance defines the amount of flow of current in the circuit.

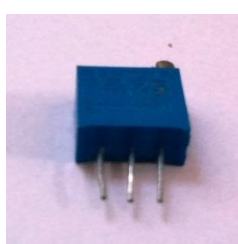


Figure 3.4 Potentiometer

3.2.1e ZENER DIODE

In this project zener diode is used in the reverse breakdown region to keep the voltage constant. It is used as a voltage regulator. A Zener diode is a special class of diode that allows current to flow in the forward direction as well as in the reverse direction if the voltage is higher than the breakdown voltage commonly referred as "Zener knee voltage". In case of large forward bias (current in the direction of the arrow), the diode exhibits a voltage drop due to its junction built-in voltage and internal resistance. The amount of the voltage drop depends on the semiconductor material and the doping concentrations. A Zener diode exhibits almost the same properties, except the device is specially designed so as to have a greatly reduced breakdown voltage, the so-called Zener voltage. By contrast with the conventional device, a reverse-biased Zener diode will exhibit a controlled breakdown and allow the current to keep the voltage across the Zener diode at the Zener voltage.

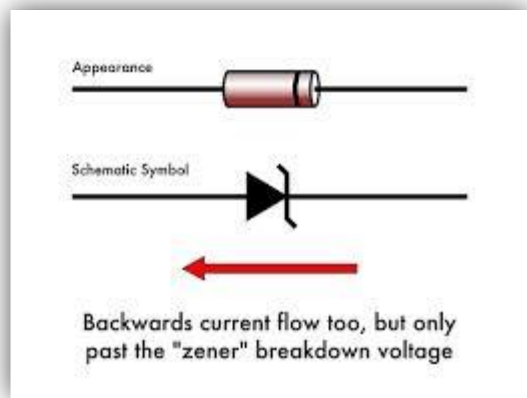


FIGURE 3.5 Zener diode

3.3 MICROCONTROLLER (AT89C52)

In the current project microcontroller AT89C52(ATMEL Corporation) was used to run the dc motor i.e. movement of the artificial limb. CMOS is an 8-bit microcomputer. It contains 8KB of Flash Programmable and Erasable Read Only Memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard 80C51and 80C52 instruction set and pin out. The on-chip Flash permits the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C52 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

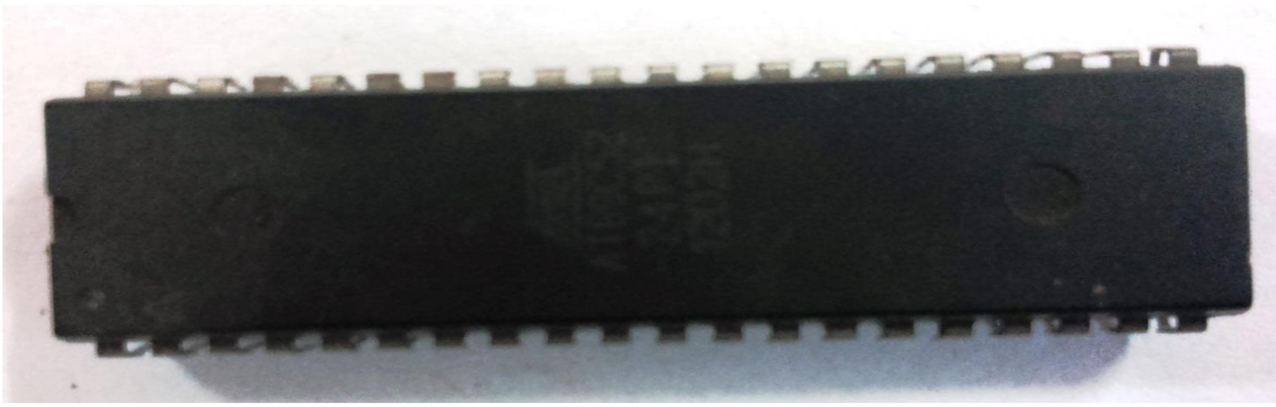


Figure 3.6 Microcontroller AT89C52 (ATMEL Corporation)

3.4 L293D MOTOR DRIVER IC

In this project IC L293D was basically used to drive the dc motor. The output from microcontroller was given to DC Motors via L293D Motor driver IC as shown in figure 3.6. The L293D motor driver IC helps in providing user ease and user friendly interfacing for embedded application. L293D motor driver was mounted on a single sided non-PTH PCB. The pins of L293D motor driver IC were connected to connectors for easy access to the driver IC's pin functions. It is a Dual Full Bridge driver that can drive up to 1Amp per bridge with supply voltage up to 24V. It can drive two DC motors, relays, solenoids, etc. and the device is TTL (Transistor Transistor Logic) compatible. Two H bridges of L293D can be connected in parallel to raise its current capacity to 2 Amp.

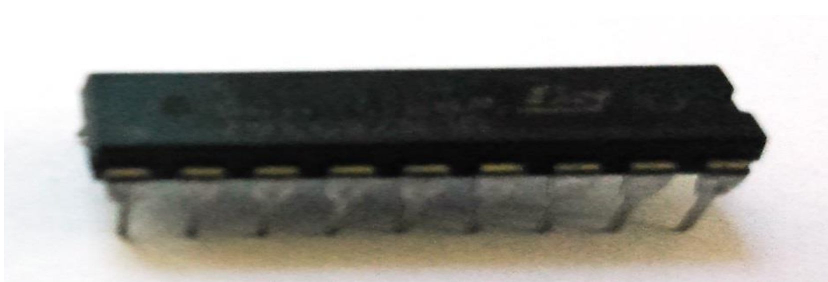


Figure 3.7 motor drivers IC

3.4.1 PIN DIAGRAM OF IC L293D

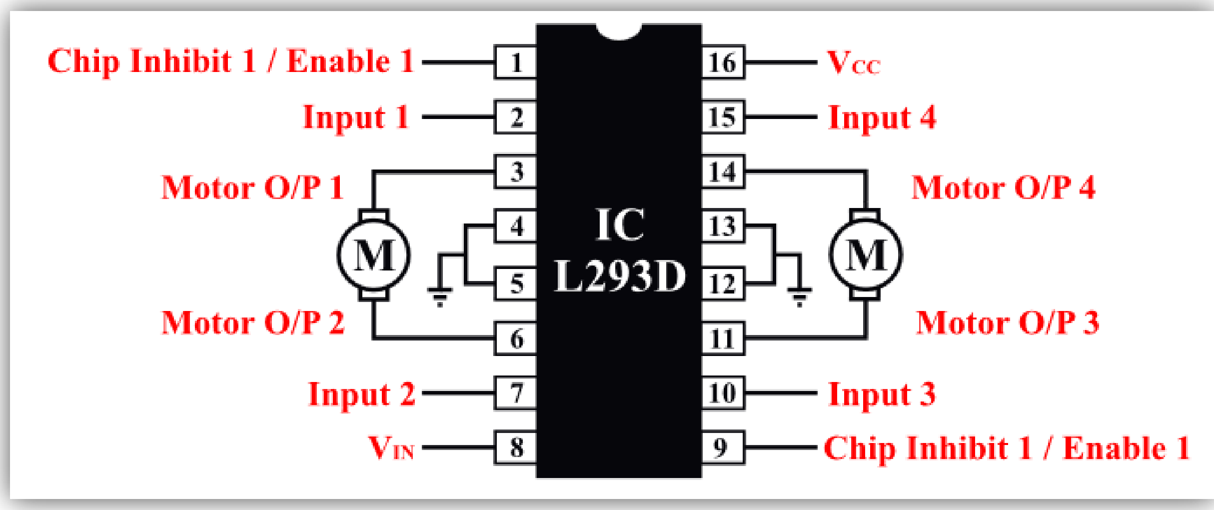


Figure 3.8 Pin diagram with motor connected

The driver IC L293D is quad push-pull drivers capable of delivering output currents to 1A per channel respectively. Each channel is controlled by a TTL-compatible logic input and each pair of drivers (a full bridge) is equipped with an inhibit input available at pin 1 and pin 9. The motor will run only when chip inhibit is at high logic i.e. chip inhibit is enabled.

3.4.2 Features

- Easily compatible with any of the system.
- Easy interfacing through FRC (Flat Ribbon Cable).
- External Power supply pin for Motors supported.
- Onboard PWM (Pulse Width Modulation) selection switch.
- 2pin Terminal Block-(Phoenix Connectors) for easy Motors Connection.

3.4.3 TECHNICAL SPECIFICATIONS

- Power Supply: Over FRC connector 5V DC External-Power 9V to 24V DC.
- Dimensional Size : 44mm x 37mm x 14mm (l x b x h)
- Temperature Range :0°C to +70 °C

3.5 Voltage Regulators

3.5.1 IC 7805

In this project t IC 7805 was used for converting the input voltage from 12 volt to 5 volt. IC 7805 is also used for regulating the input voltage from the power supply. IC7805 is a 5V Voltage Regulator that limits the voltage output to 5V and draws 5V controlled power supply.

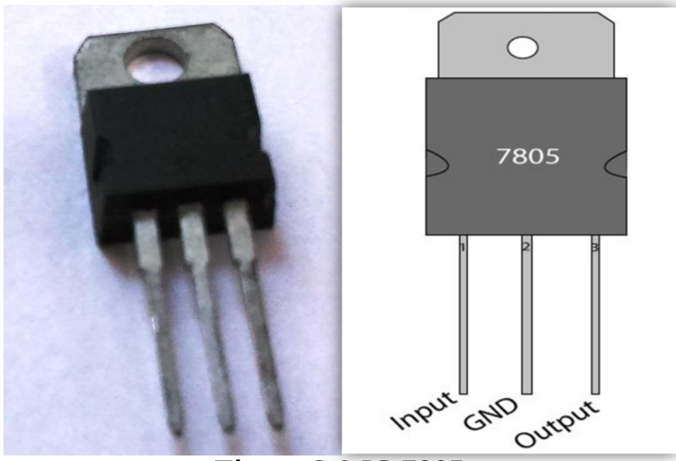


Figure 3.9 IC 7805

In some electric circuit voltage variation is fatal (for e.g. Microcontroller), for such situation to ensure constant voltage IC 7805 Voltage Regulator is used. Here DC motor input supply can be given via this IC.

In the pin configuration of IC7805, there are 3 pins, the input voltage is taken from pin 1 while the output voltage is taken from pin 3 and pin 2 is provided with GND of both input and output voltage.

Table 3.2: IC 7805 Pin Configuration

Pin No.	Function	Name
1	Input voltage (5V – 18V)	Input
2	Ground (0V)	Ground
3	Regulated Output; 5V (4.8V – 5.2V)	Output

3.5.2 IC 7905

In the current project IC 7905 was used for converting the input voltage supply from -12 volt to -5 volt. IC 7905 provides a regulated supply of -5 V and 1A current i.e. a voltage regulator integrated circuit. It is a member of 79xx series of fixed linear voltage regulator ICs. The voltage source in a circuit may have variations and it does not give the fixed output voltage.. IC7805 maintains the output voltage at a constant value. whereas xx in 78xx indicates the fixed output voltage it is designed to provide short circuit protection, internal thermal overload protection and output transistor safe operating area are some of the additional features of IC7905.In the pin configuration of IC7905, there are 3 pins, the input voltage is taken from pin 2 while the output voltage is taken from pin 3 and pin 1 is provided with GND of both input and output voltage.

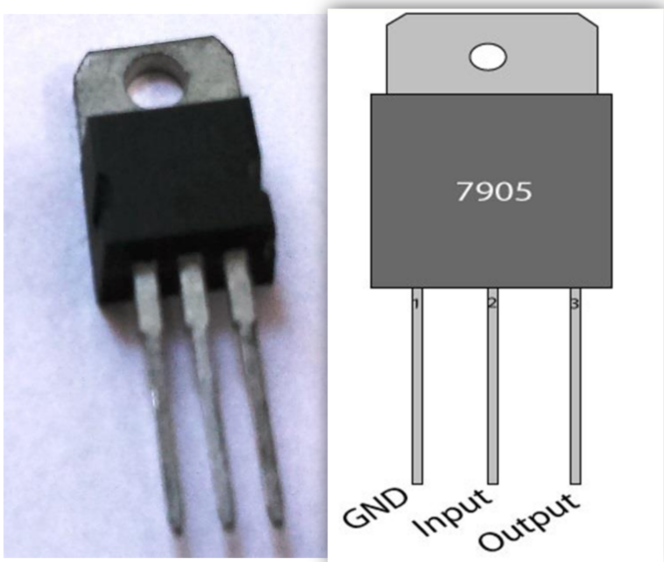


Figure 3.10 IC 7905

Table 3.3 IC 7805 Pin Configuration

Pin No.	Function	Name
1	Ground (0V)	Ground
2	Input Voltage (5V – 18V)	Input

3	Regulated Output; 5V (4.8V – 5.2V)	Output

3.4 WORKING PRINCIPLE:

Figure 3.11 Complete set up of the working model

The model was based on the pH fluctuation in the neural muscular junctions. Ringer lactate solution (pH 7) was used as artificial biological fluid. The pH of solution was altered continuously using 0.1 M NaCl and 0.1 M HCl. By adding 0.1 M NaCl drop by drop using dropper pH was increased and vice versa using 0.1 M HCl. Then the PH was measured by pH meter. The pH probe amplifier was used to convert PH value into voltage signal. When the pH of solution was decreased there was increase in voltage and the PH of solution is increased there was decrease in voltage. This voltage was measured by multimeter (MET 702). This phenomenon was used to drive the DC motor which helped for the movement of prosthetic limb in clockwise and anti-clockwise directions. This above process was monitored using microcontroller – AT89C52(ATMEL Corporation).

CHAPTER 4

RESULT AND DISCUSSION

4.1 Sample I (Ringer lactate solution and NaCl):

In order to simulate of the *in vivo* event of NMJ prior to muscle contraction, a sample of Ringer lactate solution was prepared and an alkali/acid was added drop by drop to vary the pH gradually. Briefly, for increasing the pH, 0.1M NaCl was added drop by drop, slowly from a height of 10cm at room temperature, minor changes in pH were observed with time by pH meter. pH probe was connected via the amplifier for recording the corresponding voltages. The detailed set up has been shown in figure 4.1.

Figure 4.1: Complete set up of the working model

Further it was observed that with increase in pH, the voltage decreased. The decrease in voltage can be explained by Nernst equation (Eqn 1). The addition of NaCl to the solution which is neutralising the metal ions present in the ringer lactate solution and thus, decrease in metal ions leads to decrease in voltage because of negligible ions left for conductance. Table 4.1 shows the variation in voltage with change in pH of the solution.

Nernst Equation

Nernst equation is an equation that relates the reduction potential of a half-cell (or the total voltage (electromotive force) of the full cell) at any point in time to the standard electrode potential, temperature, activity, and reaction quotient of the underlying reactions and species used. When the reaction quotient is equal to the equilibrium constant of the reaction for a given temperature, i.e. when the concentration of species are at their equilibrium values, Nernst equation gives the equilibrium voltage of the half-cell (or the full cell), which is zero; at equilibrium, Q=K, ΔG=0, and therefore, E=0.

$$E = E^0 - \frac{0.05916V}{z}\, log_{10} \frac{a_{red}}{a_{ox}} \quad \text{.....................................} (1)$$

where, E represents cell potential

E^0 represents standard cell potential

a_{red}represents reductant

a_{ox} represents oxidant

Table4.1: Variation of pH with voltage

S.No	pH value	Change in voltage(V)
1	7.0	4.5
2	7.03	4.48
3	7.16	4.462
4	7.22	4.443
5	7.29	4.40
6	7.33	4.385
7	7.38	4.365
8	7.41	4.34

9	7.46	4.324
10	7.51	4.264
11	7.56	4.23
12	7.61	4.215
13	7.70	4.205

Based on the observations a graph was plotted (shown in figure 4.2). and inferred that the voltage decreases gradually along with the increase in pH. This also infers that the concentration of Ringer lactate solution is almost directly proportional to the base solution.

As the study deals with the optimization of the mechanism of artificial limb prosthesis, the solution is prepared using Ringer lactate solution which resembles the pH of a normal human being. In artificial limb prosthesis, the limb concerned specifically is the hand. The study mainly aims in hand movement, so the solution prepared changes the pH to voltage and this in turn provides electrical signal which rotates the motor in clockwise direction.

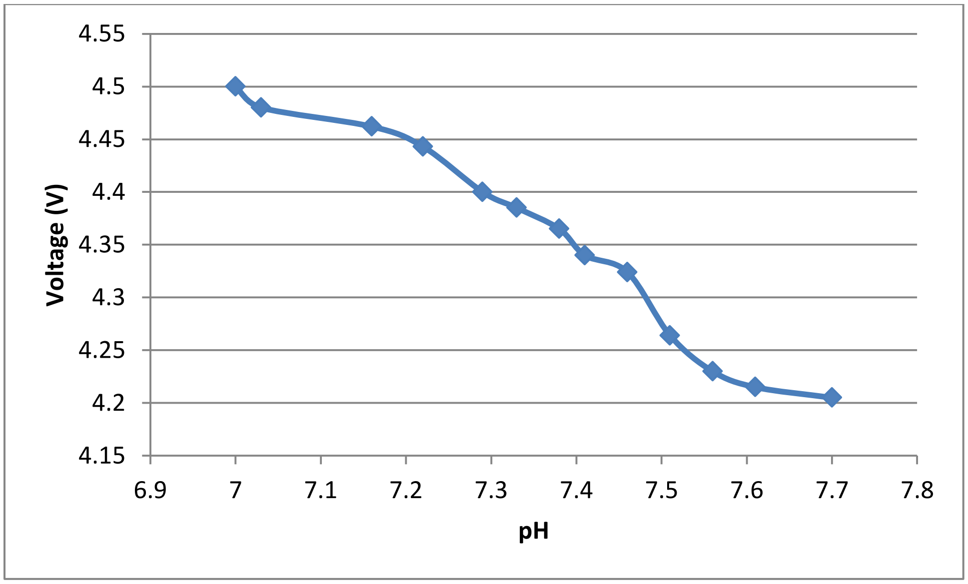


Figure 4.2: Curve of pH versus voltage

4.2 Sample II (Ringer lactate solution and HCl)

Similarly, to decrease the pH, HCl (0.1N) was added drop by drop to the prepared Ringer lactate solution at room temperature. The variations in voltage with pH change is shown in Table 5.2.

Table4.2: Variation of pH with voltage

S.No	pH value	Change in voltage(v)
1	7.0	4.5
2	6.965	4.53
3	6.943	4.55
4	6.931	4.57
5	6.91	4.612
6	6.87	4.643
7	6.83	4.66
8	6.82	4.695
9	6.79	4.7013
10	6.76	4.72
11	6.71	4.746
12	6.61	4.762
13	6.54	4.78
14	6.43	4.812
15	6.36	4.85

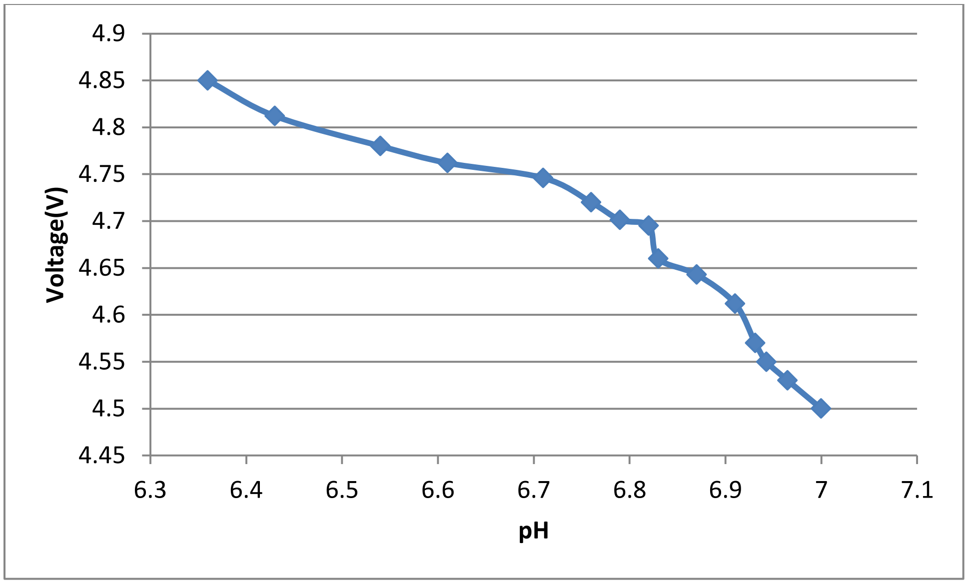


Figure 4.3: Curve of pH versus voltage

From table 4.2, it was observed that with pH decrease, the voltage increases as shown in figure 5.3. The voltage increase in this regard is due to the supply of metal ions in the ringer lactate solution which increases the positive ion concentration contents resulting in optimum voltage. In this case the motor (i.e artificial limb rotates in anticlockwise direction. Thus it is noted that with optimum solution the motor can be rotated in both the direction and this application is used to design and optimize the function of an artificial limb.

4.3 DC Motor movement with respect to voltage

The voltage which was obtained from the pH probe amplifier is amplified and given it to the microcontroller(AT89C52) and dc motor IC L293D.With the help of these voltage we are moving the artificial limb(dc motor) in clockwise and anticlockwise direction.If the voltage is greater than 4.5volt i.e pH less than 7 then motor(artificial limb) is showing the movement in clockwise direction and if voltage is less than 4.5volt i.e pH greater than 7 then motor(artificial limb) is showing the movement in anticlockwise direction. The microcontroller programme code for the motor movement is shown in Box 1.

```
sbit    M1_A=P2^0;

sbit    M1_B=P2^1;

sbit     IN_P=P2^3;
```

```
void                    DCM_Forward();

void                    DCM_Back();

void                    DCM_Stop();

void                    Delay(unsigned int tic);


void DCM_Forward()

{

        M1_A=1;

        M1_B=0;

}

void DCM_Back()

{

        M1_A=0;

        M1_B=1;

}

void DCM_Stop()

{

        M1_A=0;

        M1_B=0;

}

void Delay(unsigned int tic)

{

        char i;

        while(tic!=0)
```

```
        {
                i=140;
                while(i!=0)
                {
                i--;
                }
                tic--;
        }
}
```

Program:

```
#include<stdio.h>
#include<dadsena.h>
 void main()
{
unsigned char i;
     if IN_P>1
          for(i=0;i<10;i++)
           {
          DcM_Forward();
          Delay(10);
          if(IN_P<1)
            {  DCM_Back();
             }
            }
```

```
            DCM_Stop();
        else if
          for(i=0;i<10;i++){
            DCM_Back();
             if(IN_P>1)
             {  DCM_Forward();
              }
            Delay(10);
            DCM_Stop();
     }
   }
```

CHAPTER 6

CONCLUSION

The project focussed on fabrication of a musculoskeletal artificial limb prosthesis which worked on the principle of pH change at the neuromuscular junction. it was often thought that the only method to carry out a muscle movement was through electrical and cardiac signals which pulsated throughout the body and cause motor movements of the limbs. In the current project, it was concluded that an artificial limb movement can also be generated in response to the pH change at the neuromuscular junction that can act as information of brain centers. Though the change in pH at NMJ due to ionic movements in and out of the cells was minute, but the change was evident. The current study focuses on the conversion of these pH changes into voltage signals that can direct the switching on/off of a motor operated artificial limb through a microcontroller. Again by reversing the polarity dpending upon the voltage below or above a cut off limit exactly simulates the action of agonistic and antagonistic muscles (creating two opposite movements i.e. flexion/extension, pronation/supination, medial/lateral rotation etc.) The future work of the study focuses on development of high fidelity pH to voltage to motion system that can lead to digit movements associated with the limb movement. Apart from the pH change from change in ionic concentration (Na/K) at NMJ, ion specific electrodes (ISEs) can also be deployed to directly inform the change in specific ion concentration as input information from brain centers. Thus the sytem developed in the current study can be more effective for artificial limb development if integrated with ISEs.

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